Pulsation dampers for combustion engines

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Abstract

Fast operating injectors produce pressure pulsations because of the opening and closing of the valve. These pressure waves run through the whole injection system which causes pressure differences of $\pm 20\%$ of the mean system pressure. Therefore, the mass injection into the combustion chamber is also uneven which leads to an uncertainty in the combustion. This mismatch of the air-fuel ratio affects the performance of the combustion process and increases the emissions.

Starting with Navier-Stokes equations one can show by neglecting gravitational and viscosity influence that a change in mass flow causes a pressure wave.

$$\rho \frac{DU_j}{Dt} = \frac{\partial(\rho U_j)}{\partial t} = -\frac{\partial P}{\partial x_j} = -\frac{1}{const.} \frac{\partial P}{\partial t}$$

A typical pressure profile for an Otto injector shows exactly the above described behavior that a pressure wave runs through the entire injection system and influences the pressure in the common rail and the connected injectors. By using the commercial software AMESim, a theoretical model can be setup for a simple injection system. Afterwards one can investigate the influence of different parameters like system pressure, injection time, mass flow rate, etc. to make an analytical approach for a damped system.

$$\Delta P = \frac{8\,\mu\,\dot{V}}{\pi\,r^4}\,l$$

$$\Delta P \approx 2\,P_0\,cos\left(2\,\pi\,f\,\left(t - \frac{l}{2\,c}\right)\right)\,sin\left(2\,\pi\,f\,\frac{l}{2\,c}\right)$$

Based on these formulae one can design damper elements which can be tested afterwards. The used test-rig for the experimental studies consists of a common rail with two connected injectors and pressure sensors. It can be demonstrated that the pressure pulsations are removed completely in the common rail and in the passive injector and also mostly in the active injector. Therefore each injector can be decoupled by using these pulsation dampers because an interaction is prevented. Thus only minor pressure pulsation occur at the active injector. Furthermore, it can be shown numerically with AMESim that a dying-out time of the pressure pulsations of less than $0{,}30\ ms$ is possible. Also, different damper materials and damper configurations have been investigated numerically and experimentally to show their potential for applications and the possibility to optimize these damper elements regarding the pressure drop or the dying out time.

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